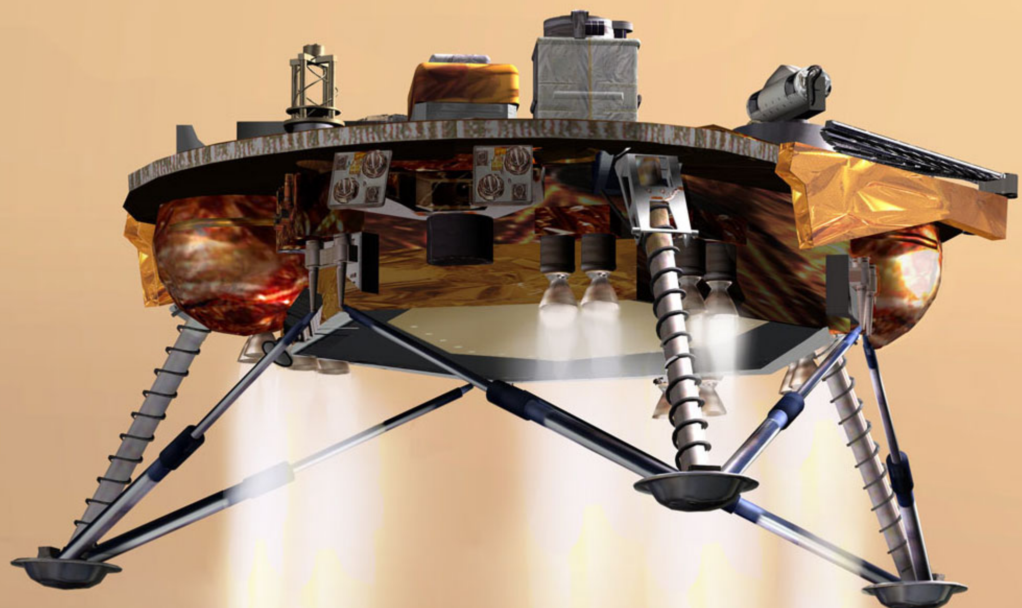
Evolution of the Phoenix EDL System Architecture



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International Planetary Probe Workshop 5
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Bordeaux, France

National Aeronautics and Space Administration
Jet Propulsion Laboratory California Institute of Technology

Presentation Overview

- The Phoenix Story
- Spacecraft Overview
- Phoenix EDL Overview
- Mission Design Comparison
- Hypersonic Subphase Evolution
- Parachute Subphase Evolution
- Terminal Descent Subphase Evolution
- Summary

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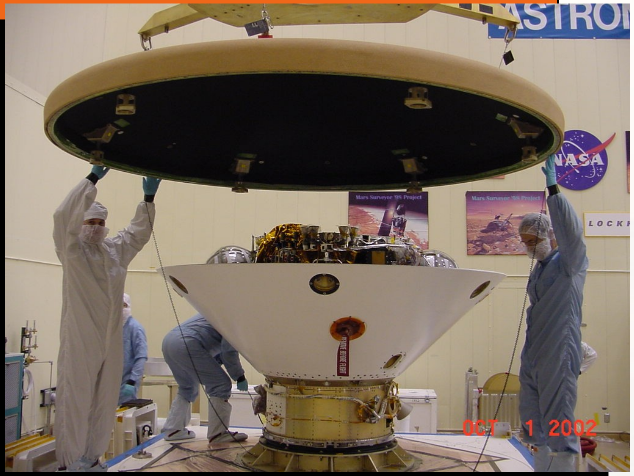
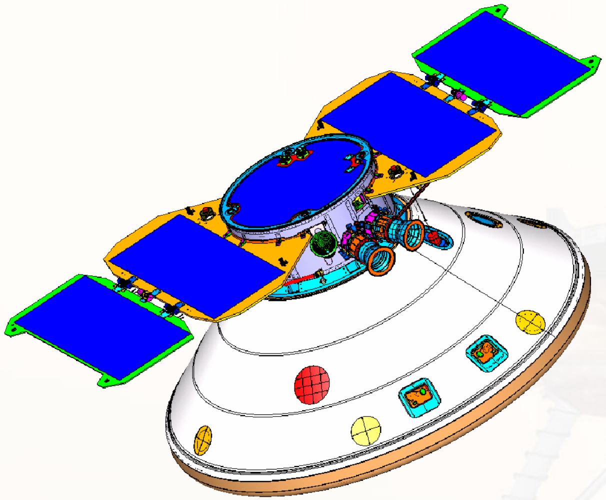
The Phoenix Story

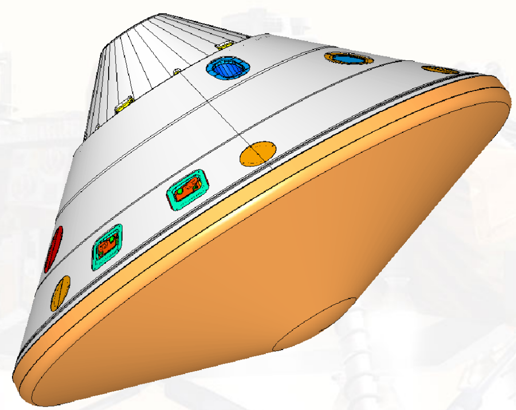
- Started as Mars Surveyor 2001 Lander
  - Faster, better, cheaper spacecraft
  - Sister spacecraft of Mars Polar Lander
  - Cancelled after Mars Polar Lander failure in 1999
    - Not enough time to address findings of MPL failure review prior to 2001 launch window
- Reborn as Phoenix in 2003
  - Same spacecraft, modified science payloads
  - Enhanced radar
  - Addition of EDL communication system
  - Enhanced test program



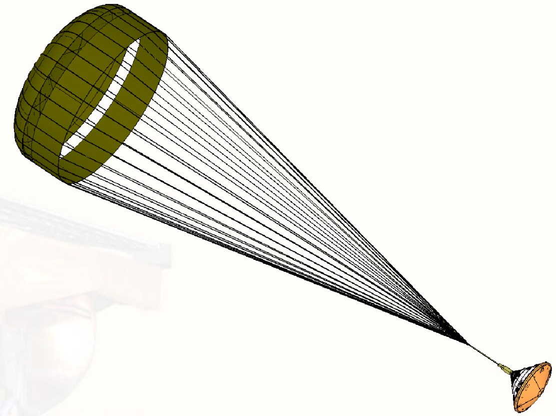
Spacecraft Overview



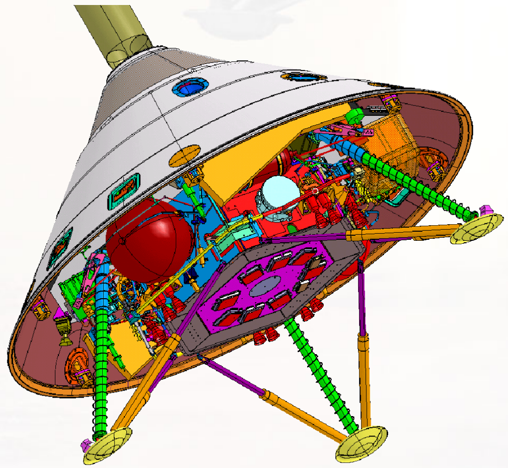
Pre-Entry Configuration



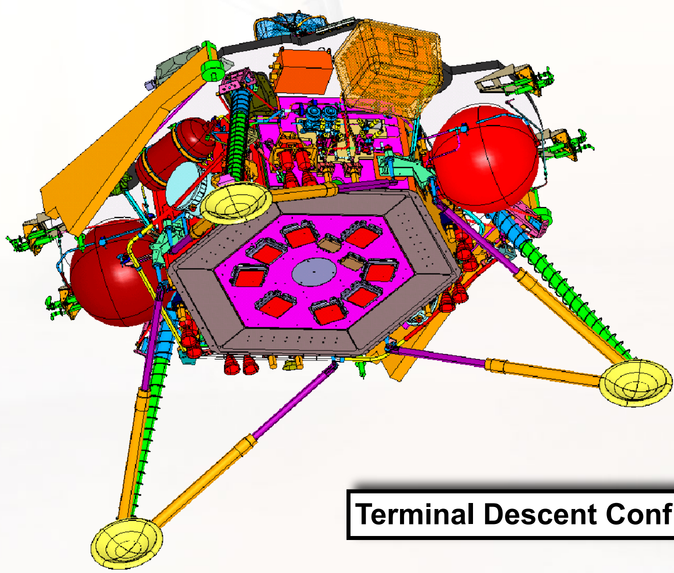
Entry Configuration



Parachute Configuration



Post HS & Leg Deploy Configuration



Terminal Descent Configuration

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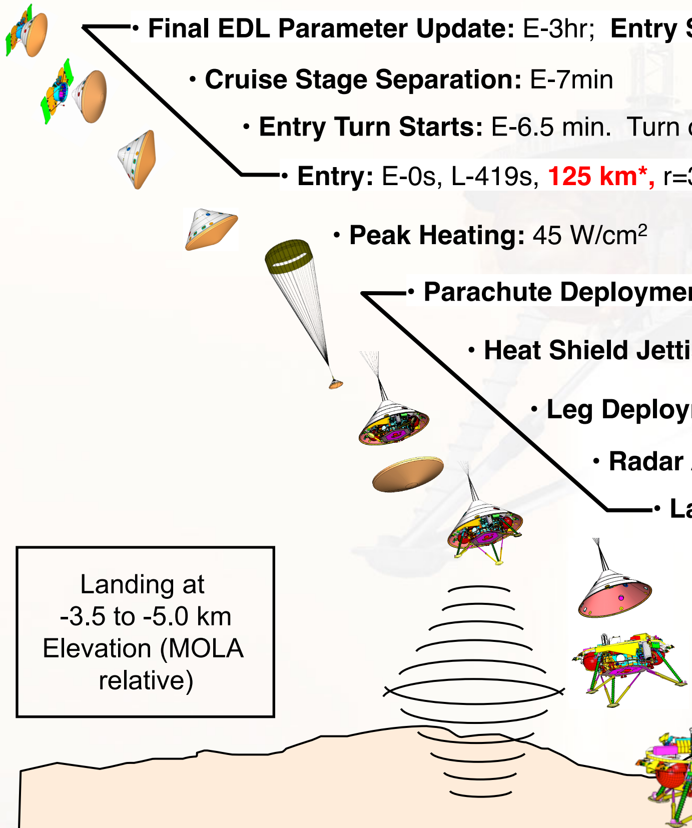
Phoenix EDL Overview



Communications: UHF-band to Orbiters

Entry Prep

- **Final EDL Parameter Update:** E-3hr; **Entry State Initialization:** E-10min
- **Cruise Stage Separation:** E-7min
- **Entry Turn Starts:** E-6.5 min. Turn completed by E-5min.
- **Entry:** E-0s, L-419s, **125 km***, r=3522.2 km, 5.6 km/s, γ = -13.0 deg

Hypersonic

- **Peak Heating:** 45 W/cm^2 **Peak Deceleration**: 9.3G

Parachute

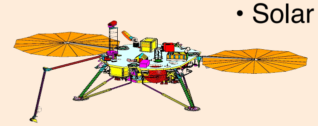
- **Parachute Deployment:** E+224s, L-195s, **11.5 km**, Mach 1.46
- **Heat Shield Jettison:** E+239s, L-180s, **9.8 km**, 109 m/s
- **Leg Deployments:** E+249s, L-170s
- **Radar Activated:** E+259s, L- 160s
- **Lander Separation:** E+382s, L-37s, **0.94 km**, 53 m/s

Terminal Descent

- **Throttle Up:** E+385s, L-34s, **0.72 km**
- **Constant Velocity Achieved:** E+404s, L-15s, **0.047 km**

Lander Prep

- **Touchdown**: E+419s, L-0s, **0 km**, Vv=2.4 ±1 m/s, Vh<1.4 m/s
- **Dust Settling:** L+0 to L+15min
- **Fire Pyros for Deployments:** L+5s
- Solar Array Deploy: L+15min
- Begin Gyro-Compassing: L+75min



Landing at -3.5 to -5.0 km Elevation (MOLA relative)

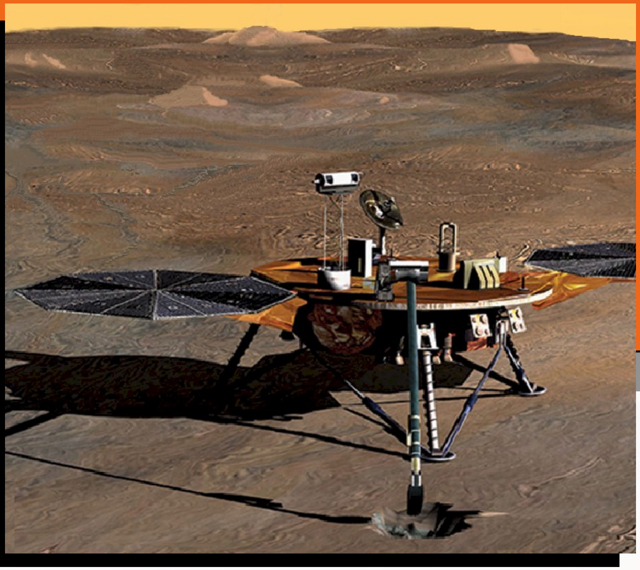
* Entry altitude referenced to equatorial radius. All other altitudes referenced to ground level

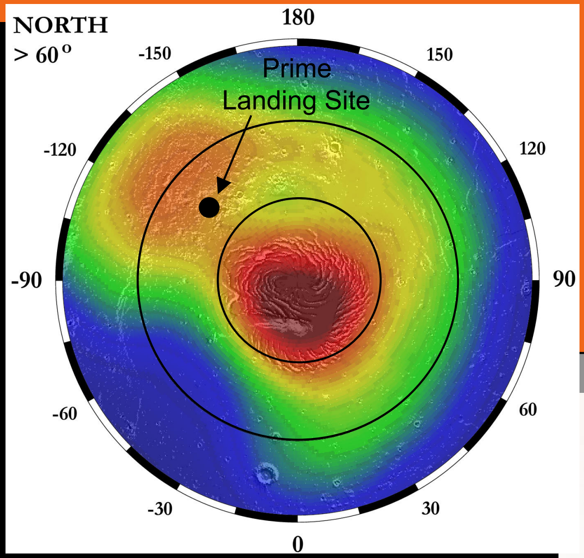
Note: Information in this graphic represents a nominal entry (67.5N Open, -3.7 km site elevation). Dispersions exist around all values.

Apr 2007

Mission Design Comparison

- **Mars 2001 Lander**
  - **Equatorial landing region**
  - **7.0 km/s entry velocity**
  - **+2.5 km (w.r.t MOLA) landing site elevation**
- **Phoenix Lander**
  - **Northern landing region: 65º N to 72º N**
  - **5.8 km/s entry velocity** ⇐ **Key Change**
  - **-3.5 km (w.r.t MOLA) landing site elevation** ⇐ **Key Change**





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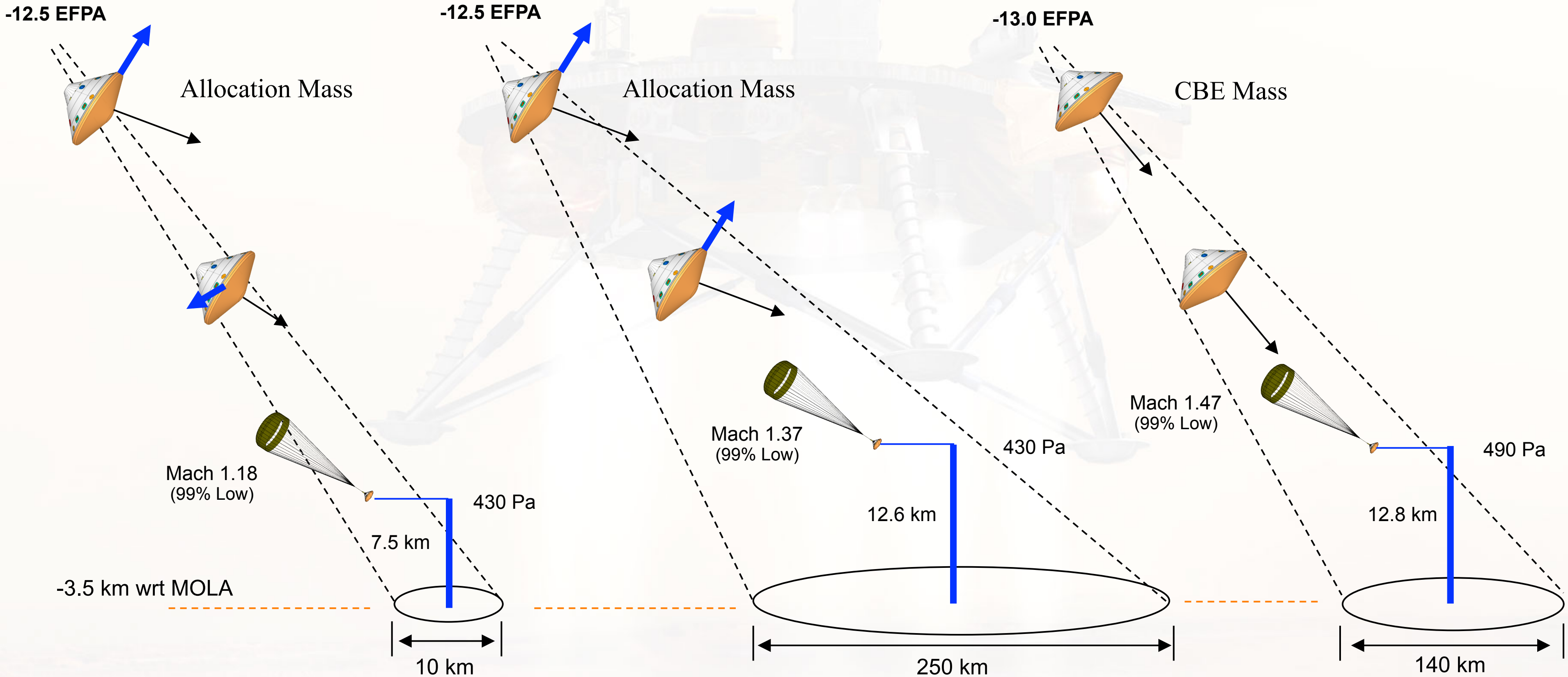
Hypersonic Subphase Evolution (1/2)

2004	2005	2006
Guided Trajectory (Ballistic Reference)	**Lifting Trajectory**	**Ballistic Trajectory**

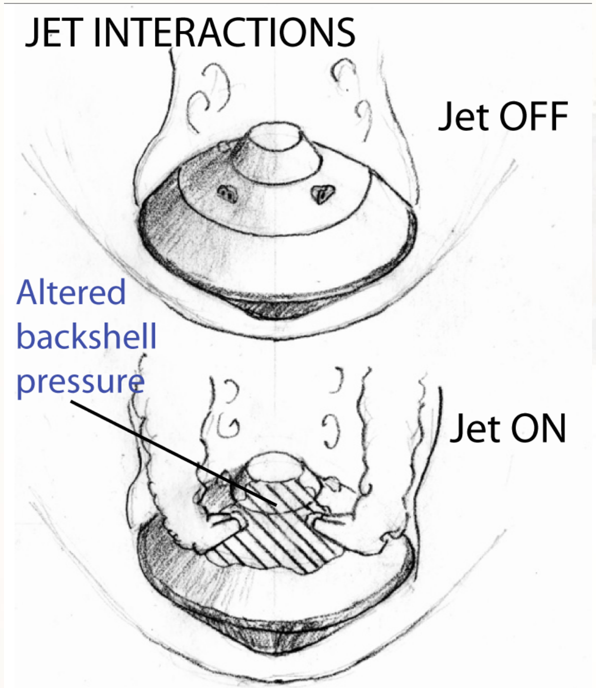


Redesign Drivers
- Reduced complexity
- Higher chute deploy Mach & altitude
- Small design change

Redesign Drivers
- Reduced footprint

Hypersonic Subphase Evolution (2/2)

Aero/RCS Flow Interaction Phenomenon

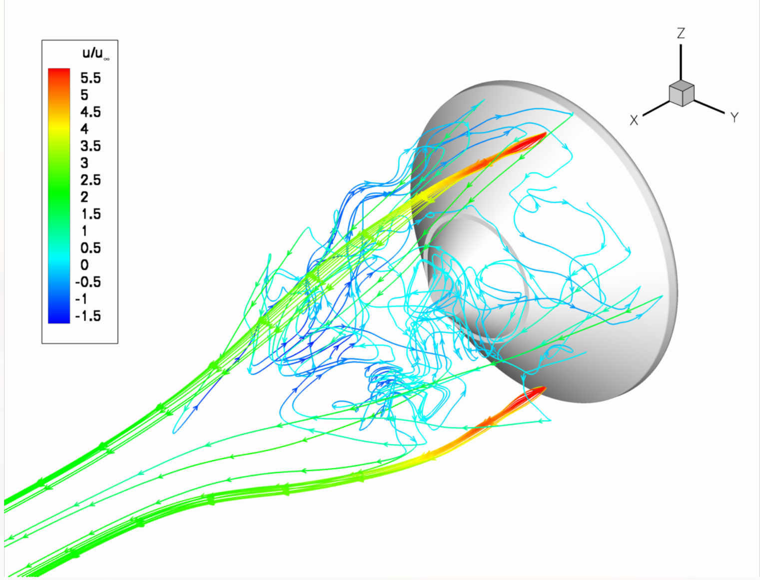


Jets can alter pressure on backshell, resulting in different control moments than intended

Control Deadbands

Pitch: 10 deg → 15 deg
Yaw: 10 deg → 15 deg
Roll: 5 deg → Inf Deadband

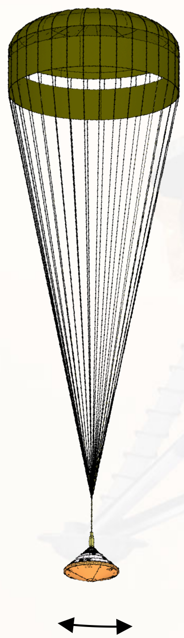
- **CFD of Aero/RCS flow field shows potential for strong interaction from hypersonic regime to parachute deployment**
  - **RCS Pitch authority is degraded**
  - **RCS Yaw authority is low to non-existent (potential for control reversal exists)**
  - **Baseline is to increase control system deadbands to minimize/eliminate RCS thruster firings to avoid this flow interaction**



CFD of Yaw Thruster Firing

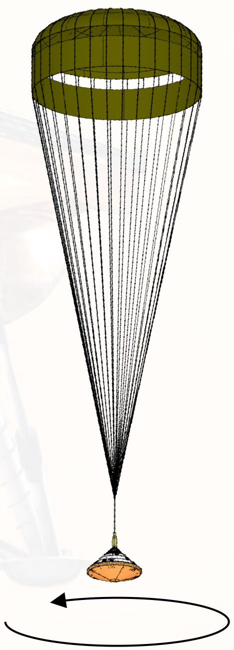
Parachute Subphase Evolution

2004
Entry Vehicle Azimuth Control



20º Azimuth Control on Parachute

2006
No Entry Vehicle Azimuth Control



No Azimuth Control on Parachute

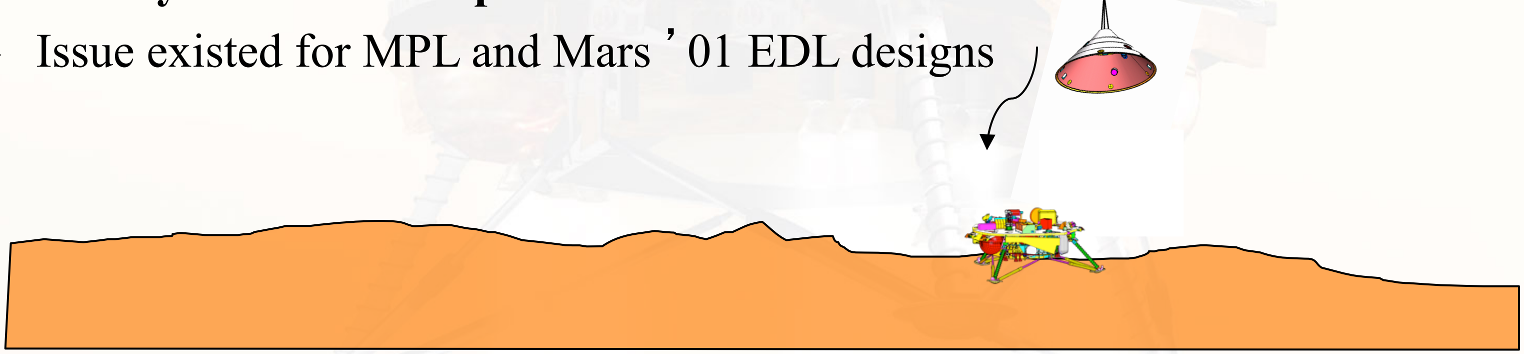
- **Originally, azimuth control was used on parachute to reduce roll needed during terminal descent – risk mitigation**
- **Because of uncertainty of thruster behavior even while on the parachute, subsequent analysis showed ability to meet azimuth requirement while doing all azimuth control during terminal descent**

Terminal Descent Subphase Evolution (1/2)

Terminal Descent Redesign Driver

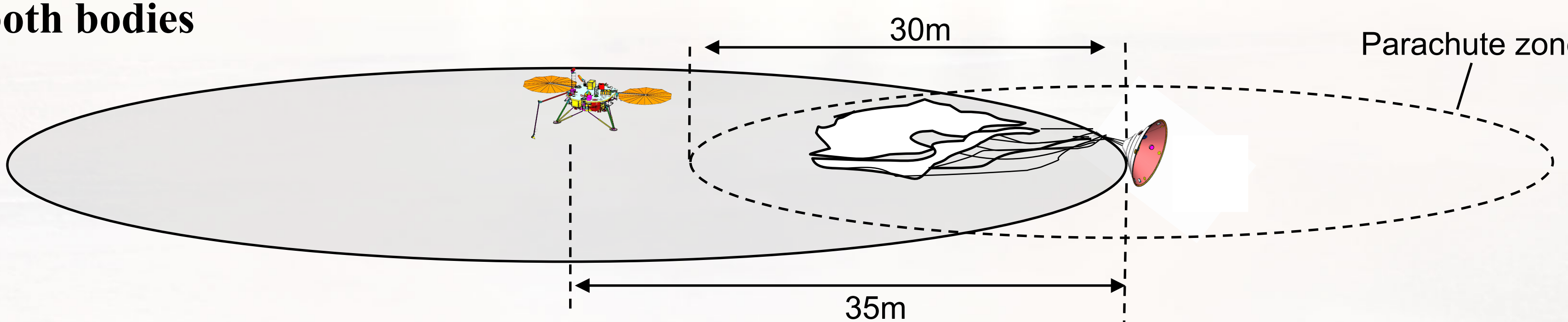
In cases of low wind and no wind terminal descent scenarios, there is an increased probability the backshell/parachute will recontact the lander

– Issue existed for MPL and Mars ’01 EDL designs



New Requirement

The distance between the center of mass of the lander and center of mass of the backshell shall be greater than 35m from 5s after lander separation to touchdown of both bodies



Terminal Descent Subphase Evolution (1/2)

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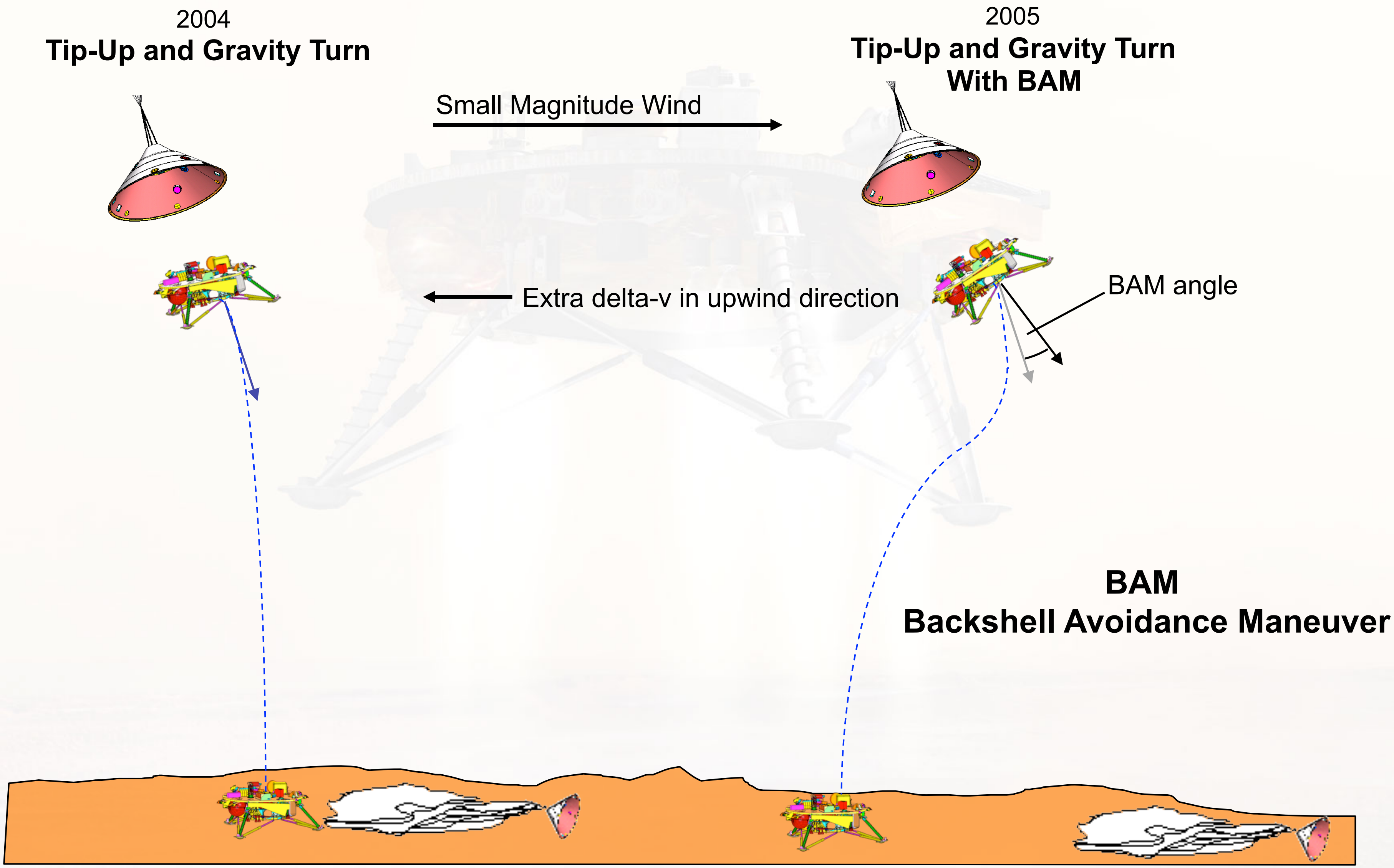

Summary

- Phoenix is a return to flight of the cancelled Mars ’01 Lander, emphasizing thorough and extensive testing
- Mission design leads to more benign entry velocities and a much lower landing site elevation relieving pressure on TPS performance and EDL timeline
- Due to complexity, hypersonic guidance was de-scoped and flight baseline is a simple ballistic entry
- Incomplete understanding of thruster effectiveness in hypersonic/ supersonic flow led to relaxed use of attitude control
- A backshell avoidance maneuver was added to mitigate risk of backshell/parachute recontact of the Lander during terminal descent and at touhdown
- Changes to Phoenix EDL system architecture provides a more robust design for Mars EDL


Phoenix Mars Mission
Launch Window
August 3 – August 24, 2007
Landing Date
May 25 or June 5, 2008
Studying the history of water and habitability potential of the Martian artic